Section 2 Heat Transfer

Objectives

After this lesson, students will be able to

I.2.2.1 Describe how temperature is measured.

I.2.2.2 Identify three ways in which heat is transferred.

I.2.2.3 Explain how heat is transferred in the troposphere.

Target Reading Skill

Outlining Explain that using an outline format helps organize information by main topic, subtopic, and details.

Answers

Heat Transfer

I. Thermal energy and temperature
   A. Measuring temperature
   B. Temperature scales
II. How Heat Is Transferred
   A. Radiation
   B. Conduction
   C. Convection
   D. Heating the troposphere

All in One Teaching Resources

- Transparency I13

Preteach

Build Background Knowledge L1

Hot Air Rising

Ask: **On a hot sunny day, have you ever seen cars, buildings, or other objects appear to shimmer or waver on the other side of a street or parking lot?** *(Most students will probably say yes.)* **What causes this effect?** *(Hot air rising from the pavement)* Explain that the sun heats up the ground more quickly than it heats the air, especially if the surface of the ground is a dark color. The heated air then rises and bends light waves as it passes through them, making objects on the other side shimmer.

Section 2 Heat Transfer

Reading Preview

Key Concepts

- How is temperature measured?
- In what three ways is heat transferred?
- How is heat transferred in the troposphere?

Key Terms

- temperature
- thermal energy
- thermometer
- heat
- conduction
- convection
- convection currents

Target Reading Skill

Outlining As you read, make an outline about how heat is transferred. Use the red headings for the main topics and the blue headings for the subtopics.

Heat Transfer

I. Thermal energy and temperature
   A. Measuring temperature
   B.
II. How heat is transferred
   A.

Lab zone Discover Activity

What Happens When Air Is Heated?

1. Use heavy scissors to cut the flat part out of an aluminum pie plate. Use the tip of the scissors to poke a small hole in the middle of the flat part of the plate.
2. Cut the part into a spiral shape, as shown in the photo. Tie a 30-centimeter piece of thread to the middle of the spiral.
3. Hold the spiral over a source of heat, such as a candle, hot plate, or incandescent light bulb.

Think It Over

Inferring What happened to the spiral? Why do you think this happened?

You pour a cup of steaming tea from a teapot. Your teacup is warm to the touch. Somehow, heat was transferred from one object (the cup) to another (your hand) that it was touching. This is an example of conduction, one of three ways that heat can be transferred. As you'll learn in this section, heat transfer in the troposphere plays an important role in influencing Earth's weather.

It takes only a small amount of energy to heat up a cup of tea. ▶

Lab zone Discover Activity

Skills Focus Inferring L1

Materials aluminum pie plate; heavy scissors; thread; candle, hot plate, or incandescent light

Time 10 minutes

Tips CAUTION: *Closely supervise students who are working around a candle or a hot plate.*

Advise students to be careful when using the scissors. You may want to poke holes in the flat parts yourself.

Expected Outcome The spiral will spin.

Think It Over The spiral spun because warm air rose from the heat source and pushed against the spiral.

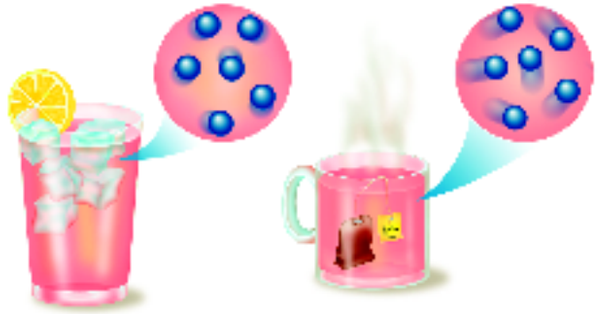

FIGURE 4
Movement of Molecules The iced tea is cold, so its molecules move slowly. The herbal tea is hot, so its molecules move faster than the molecules in the iced tea.
Inferring *Which liquid has a higher temperature?*

Thermal Energy and Temperature

The tea in the cup and in the teapot are at the same temperature but have a different amount of total energy. To understand this, you need to know that all substances are made up of tiny particles that are constantly moving. The faster the particles are moving, the more energy they have. Figure 4 shows how the motion of the particles is related to the amount of energy they hold. **Temperature** is the *average* amount of energy of motion of each particle of a substance. That is, temperature is a measure of how hot or cold a substance is. In contrast, the *total* energy of motion in the particles of a substance is called **thermal energy.** The hot tea in the teapot has more thermal energy than the hot tea in the cup because it has more particles.

Measuring Temperature Temperature is one of the most important factors affecting the weather. **Air temperature is usually measured with a thermometer.** A **thermometer** is a thin glass tube with a bulb on one end that contains a liquid, usually mercury or colored alcohol.

Thermometers work because liquids expand when they are heated and contract when they are cooled. When the air temperature increases, the temperature of the liquid in the bulb also increases. This causes the liquid to expand and rise up the column.

Temperature Scales Temperature is measured in units called degrees. Two temperature scales are commonly used: the Celsius scale and the Fahrenheit scale. Scientists use the Celsius scale. On the Celsius scale, the freezing point of pure water is 0°C (read "zero degrees Celsius"). The boiling point of pure water at sea level is 100°C. Weather reports in the United States use the Fahrenheit scale. On the Fahrenheit scale, the freezing point of water is 32°F and the boiling point is 212°F.

Reading Checkpoint **Which temperature scale do scientists use?**

Math Skills

Converting Units

Temperatures in weather reports use the Fahrenheit scale, but scientists use the Celsius scale. Temperature readings can be converted from the Fahrenheit scale to the Celsius scale using the following equation:

$$°C = \frac{5}{9}(°F - 32)$$

If the temperature is 68°F, what is the temperature in degrees Celsius?

$$°C = \frac{5}{9}(68 - 32)$$

$$°C = 20°C$$

Practice Problem Use the equation to convert the following temperatures from Fahrenheit to Celsius: 35.0°F, 60.0°F, and 72.0°F.

Thermal Energy and Temperature

Teach Key Concepts L1

Thermal Energy Versus Temperature

Focus Ask students to name the scale commonly used by the public in the United States. *(Fahrenheit)*

Teach Explain that temperature is the average amount of energy of a substance, whereas thermal energy is the total amount. Ask: **What is being measured by an outdoor thermometer?** *(Temperature of the air)* **What are the freezing and boiling points of water at sea level for the Celsius scale and the Fahrenheit scale?** *(0° and 100°; 32° and 212°)*

Apply Ask: **Why do you think scientists use the Celsius scale?** *(It is more convenient to work with a system that has multiples of ten; it fits better with the metric system. Scientists all over the world have agreed to use this scale as the standard.)* **learning modality: logical/mathematical**

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Heat Transfer*

Student Edition on Audio CD

Math Skills

Math Skills Converting Units

Focus Tell students that scientists in the United States also use the Celsius scale.

Teach Remind students to do the calculation in the parentheses (68 – 32 = 36) first. Then multiply 36 by the numerator (5) and divide by the denominator (9).

Answers
1.67°C, 15.6°C, 22.2°C

Gifted and Talented

Monitor Progress L2

Skills Check Ask students to compare and contrast the Fahrenheit and Celsius scales.

Answers
Figure 4 The hot herbal tea

Reading Checkpoint The Celsius scale

Differentiated Instruction

Creating a Conversion Chart Have L3 students develop a large, colorful temperature scale showing temperatures in Fahrenheit and Celsius on either side. Challenge them to provide familiar examples of temperatures for each scale, such as human body temperature or the average temperature of their city in winter. **learning modality: visual**

Special Needs L1
Converting Temperature Readings
Provide each student with an index card listing the steps for conversion:

1. Write the Fahrenheit temperature.
2. Subtract 32.
3. Multiply the result by 5.
4. Divide the result by 9.
5. The result is the Celsius temperature.

Go Online SCI LINKS NSTA

For: Links on heat transfer
Visit: www.SciLinks.org
Web Code: scn-0922

Download a worksheet that will guide students' review of Internet resources on heat transfer.

How Heat Is Transferred

Teach Key Concepts

Types of Heat Transfer L1

Focus Point out that temperature is a measurement of the average amount of energy of motion of the particles in a substance, whereas heat is thermal energy that is moving.

Teach Refer students to Figure 5. Call out one of the labels in the figure, and have volunteers describe its meaning.

Apply Ask: **Why are heat vents placed near the floor?** *(Hot air rises; if the vents were higher, the lower part of the room would not receive heat.)* **learning modality: logical/mathematical**

Lab zone Build Inquiry L2

Modeling Heat Transfer

Materials ball

Time 5 minutes

Focus Review the types of heat transfer.

Teach Have students use balls to represent heat and themselves to represent air molecules as they work in pairs or small groups to model the types of heat transfer. Examples are tossing or rolling the ball (radiation), passing the ball between students (conduction), and walking with a ball (convection).

Apply Encourage students to give everyday examples of each type of heat transfer. **learning modality: kinesthetic**

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Lab zone Try This Activity

Temperature and Height

How much difference is there between air temperatures near the ground and higher up? Give reasons for your prediction.

1. Take all of your measurements outside at a location that is sunny all day.
2. Early in the morning, measure the air temperature 1 cm and 1.25 m above the ground. Record the time and temperature for each height. Repeat your measurements late in the afternoon.
3. Repeat Step 2 for two more days.
4. Graph your data for each height with temperature on the vertical axis and time of day on the horizontal axis. Use the same graph paper and same scale for each graph. Label each graph.

Interpreting Data At which height did the temperature vary the most? How can you explain the difference?

How Heat Is Transferred

Heat is the transfer of thermal energy from a hotter object to a cooler one. **Heat is transferred in three ways: radiation, conduction, and convection.**

Radiation Have you ever felt the warmth of the sun's rays on your face? You were feeling energy coming directly from the sun as radiation. Recall that radiation is the direct transfer of energy by electromagnetic waves. Most of the heat you feel from the sun travels to you as infrared radiation. You cannot see infrared radiation, but you can feel it as heat.

Conduction Have you ever walked barefoot on hot sand? Your feet felt hot because heat moved directly from the sand into your feet. The direct transfer of heat from one substance to another substance that it is touching is called **conduction.** When a fast-moving sand molecule bumps into a slower-moving molecule, the faster molecule transfers some of its energy.

The closer together the atoms or molecules in a substance are, the more effectively they can conduct heat. Conduction works well in some solids, such as metals, but not as well in liquids and gases. Air and water do not conduct heat very well.

Convection In fluids (liquids and gases), particles can move easily from one place to another. As the particles move, their energy goes along with them. The transfer of heat by the movement of a fluid is called **convection.**

Heating the Troposphere **Radiation, conduction, and convection work together to heat the troposphere.** During the day, the sun's radiation heats Earth's surface. The land becomes warmer than the air. Air near Earth's surface is warmed by both radiation and conduction. However, heat is not easily transferred from one air particle to another by conduction. Only the first few meters of the troposphere are heated by conduction. Thus, the air close to the ground is usually warmer than the air a few meters up.

Within the troposphere, heat is transferred mostly by convection. When the air near the ground is heated, its particles move more rapidly. As a result, they bump into each other and move farther apart. The air becomes less dense. Cooler, denser air sinks toward the surface, forcing the warmer air to rise. The upward movement of warm air and the downward movement of cool air form **convection currents.** Convection currents move heat throughout the troposphere.

Reading Checkpoint **How is the air near Earth's surface heated?**

Lab zone Try This Activity

Skills Focus Interpreting data L2

Materials 2 thermometers, metric tape measure, watch or clock, graph paper

Time 10 minutes per day for 3 days; 20 minutes to graph and analyze data

Tips Doing this activity on sunny days will lead to greater differences in temperature at the two heights

Expected Outcome Students should find that the temperature 1 cm above the ground varies more than the temperature 1.25 m above the ground. The ground heats up during the day as it absorbs sunlight. It cools quickly at night as it radiates the heat back into the air. Heat is not effectively transferred through air, so air close to the ground will be more affected by these variations in ground temperature than air farther above the ground.

Extend Have students repeat the activity in a shady location and then compare the data obtained from the two locations. They should find less variation in the shady-location readings. Challenge students to explain why. **learning modality: logical/mathematical**

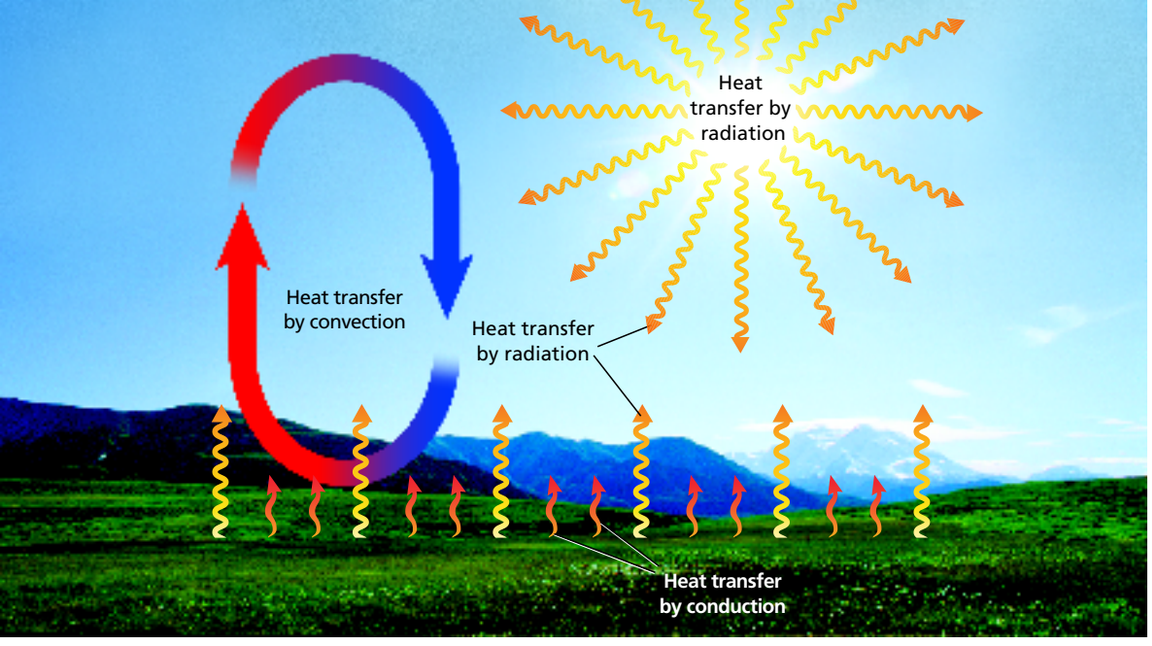

FIGURE 5
Heat Transfer
All three types of heat transfer—radiation, conduction, and convection—occur near Earth's surface.

Section 2 Assessment

Target Reading Skill **Outlining** Use the information in your outline about heat transfer to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is temperature?
   b. **Identifying** What instrument is used to measure air temperature?
   c. **Comparing and Contrasting** A pail of water is the same temperature as a lake. Compare the amount of thermal energy of the water in the lake and the water in the pail.
2. a. **Naming** Name three ways that heat can be transferred.
   b. **Describing** How do the three types of heat transfer work together to heat the troposphere?
   c. **Identifying** What is the major way that heat is transferred in the troposphere?
   d. **Applying Concepts** Explain how a hawk or eagle can sometimes soar upward without flapping its wings.

Math Practice

3. **Converting Units** Use the equation from the Math Skills Activity to convert the following temperatures from Fahrenheit to Celsius: 52°F, 86°F, 77°F, and 97°F.

Monitor Progress L2

Answers

Reading Checkpoint By all three types of heat transfer—radiation, convection, and conduction

Assess

Reviewing Key Concepts

1. a. Temperature is the average amount of energy of motion of each particle of a substance. **b.** Thermometer **c.** The water in the lake has more thermal energy because it is much greater than the water in the pail.
2. a. By radiation, by convection, and by conduction **b.** The sun transfers heat to Earth by radiation. As Earth warms, it re-radiates heat to the atmosphere and conducts heat to gas molecules near the surface. This heat is transferred throughout the troposphere by convection.
c. convection **d.** The bird circles in a convection current of rising warm air

3. **Math Practice** 11°C, 30°C, 25°C, and 36°C

Reteach L1

Have students draw a diagram to show how heat is transferred from Earth's surface to the atmosphere.

All in One Teaching Resources

- Section Summary: *Heat Transfer*
- Review and Reinforce: *Heat Transfer*
- Enrich: *Heat Transfer*
- Transparency I14

Lab zone Chapter Project

Keep Students on Track Check that students have gathered all the materials that they need. Offer to meet with students to clarify any written instructions for building the instruments. Check that the building plans are not too complex and that they do not require expensive or hard-to-find materials.